Fertilizing Onion Sets, Sweet Corn, Cabbage, and Cucumbers in a Four-Year Rotation

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CONTENTS

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Fertilizing Onion Sets, Sweet Corn, Cabbage, and Cucumbers in a Four-Year Rotation

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LOCAL PRODUCTION of vegetables near large consuming centers continues to be an important factor in supplying the vegetable needs of Illinois cities. This has remained true notwithstanding the enormous development of vegetable production in favored localities at varying distances from Illinois markets and great improvement in transportation facilities for perishable products. In the vicinity of Chicago, which contains over half the population of the state and which receives vegetable supplies from all domestic producing areas and several foreign countries, local production of vegetables is still an important industry, approximately 1,800 of the 3,200 farms within the borders of Cook county producing vegetables for market.

The substitution of motor vehicles for horses in the cities has profoundly affected the vegetable industry by greatly reducing the available supply of fresh animal manure. This situation has necessitated a search for other means of maintaining soil fertility in the vegetable-growing areas. Furthermore it is now generally known that stable manure is not a well-balanced fertilizer, and if used in sufficient quantities to furnish enough phosphorus for most vegetable crops, will supply an excess of nitrogen and potash, and cause the gardener to incur needless expense.

In any program of soil maintenance or improvement a definite rotation of crops is usually deemed advisable. Four of the most important vegetable crops grown in the Chicago area are onion sets,[1] sweet corn for market, cabbage, and pickle cucumbers. Therefore, for an experiment in northeastern Illinois planned with a view to developing a workable method of fertilizing vegetable crops without the use of large quantities of manure, these four crops were selected and arranged in a four-year rotation in such a way as to permit the growing of at least three green-manuring crops, in addition to the four cash crops, in each four-year period.

[1]It has been estimated that Cook county, Illinois, produces at least 80 percent of the onion-set crop of the United States.

PLAN OF EXPERIMENT

The experiment was carried on at the Cook County Branch Experiment Station from 1925 to 1936 inclusive, on soil consisting principally of Lisbon clay loam and silty clay loam, Saybrook silt loam, and Elliott clay loam. These soils are common in the market garden region in the northern part of Cook county and adjacent territory.

Cropping Scheme

Each plot consisted of $\frac{1}{40}$ acre from which the yield records were taken. Alleys 8 feet wide were left between plots. Plants in the alleys were cut out before the beginning of the harvest period or harvested in advance of the harvest for record.

In the main series of plots (Series I) the following plan of cropping for the four main crops and the cover crops was carried out:

Onion seed for the production of sets was sown early in the spring. The sets were harvested in August, and the land was then seeded to a mixture of rye and vetch as a cover crop which was plowed under for green manure before corn-planting time the next spring.

Sweet corn was planted for an early market crop. Either at the time of the last cultivation or immediately after the green corn was harvested, the land was seeded to sweet clover. The sweet clover was plowed down for green manure before time for planting late cabbage the next season.

Cabbage was transplanted to the field in June. The original plan was to seed rye after harvesting the cabbage, but in practice it was found that the cabbage matured too late to permit the starting of a cover crop, even of rye, the same fall. Therefore, no cover crop followed the cabbage.

Pickle cucumbers were planted in late May or early June, after fall plowing. As soon as the harvest was completed, usually by September 10, a cover crop of oats was sown. This cover crop was plowed under late in the fall, preparatory to the seeding of onions early the next spring, to start the next cycle of the rotation.

Thus, four cash crops and three cover or green-manuring crops were grown on the same land in four years.

In addition to the foregoing series of plots with cover crops, another small series (Series II) was planted without any cover crops, so that a comparison might be made between manure and a complete commercial fertilizer for maintaining the productivity of the soil.

The various plots were replicated so that all four vegetable crops were grown every year, thus making yield records available on each

crop for each of the twelve years representing the three full rotations, except in years of crop failure or other eventualities. Each year the various treatments for each crop were duplicated.

Kinds and Amounts of Fertilizer Applied

In Series I cover crops were used without manure on all plots, including the check plots, for maintaining the supply of organic matter in the soil. Different fertilizer mixtures were added to the various plots in order to test their effectiveness in producing satisfactory yields of the respective crops. Each treated plot was adjacent to an untreated check plot. All plots treated with commercial fertilizers were given an annual application at the rate of 1,000 pounds to the acre, the material being scattered broadcast over the surface of the ground and thoroly mixed with the top soil by disking and harrowing during the preparation of the seedbed. The fertilized area of each plot extended to the centers of the adjacent alleys.

In making up the different fertilizer mixtures, the three elements—nitrogen, phosphorus, and potassium—were used in varying proportions, representing from 0 to 6 percent nitrogen, from 0 to 12 percent phosphorus, and from 0 to 6 percent potassium. In each mixture containing nitrogen, half the nitrogen was derived from nitrate of soda and half from ammonium sulfate. Superphosphate was used as the source of phosphorus and muriate of potash as the source of potassium. In Series II the applications of commercial fertilizer were made in the same amounts and in the same manner as in Series I; the manure was applied broadcast at the rate of 20 tons to the acre just before plowing. In this series all plowing was done in the fall.

Applications of 1,000 pounds of commercial fertilizer or 20 tons of manure to the acre were considered about normal for the production of vegetables on market garden soils in northern Illinois at the time this experiment was started. The various treatments in both Series I and Series II are shown in Table 1.

Planting and Handling the Crops

Onion sets. The onion seed for the production of sets was sown in rows 14 inches apart, at the rate of 70 pounds to the acre. The Yellow Strassburg variety was used from 1925 to 1931 inclusive; and the Ebenezer from 1932 to 1936 inclusive.[1] Tillage with wheel hoes

[1]When this experiment was started, the Yellow Strassburg variety was used almost exclusively for the production of yellow onion sets in the Chicago area. After this variety was replaced by Ebenezer in plantings of commerical growers, the shift to the latter variety was made in the experiment.

TABLE 1.—FERTILIZER APPLICATIONS PER ACRE PER YEAR IN EXPERIMENTS WITH ONION SETS, SWEET CORN, CABBAGE, AND CUCUMBERS (1925-1936)

Series	Treatment No.	Fertilizer	
		Kind	Amount
		N-P-K	*lb. or (tons)*
Series I, *with* cover crops	1	0-8-4	1000
	2	4-8-4	1000
	3	6-8-4	1000
	4	4-0-4	1000
	5	4-4-4	1000
	6	4-12-4	1000
	7	4-8-0	1000
	8	4-8-6	1000
Series II, *without* cover crops	1	4-8-4	1000
	2	Manure	(20 T)

and hand-weeding were employed in the care of the crop. The sets were harvested as soon as mature, and were placed in shallow, slatted crates which were stacked up in the usual manner for curing of the crop. At the approach of cold weather, the sets were weighed and sampled, and the yield records taken, before the crop was placed in winter storage. There were very few "overruns" (bulbs too large to be acceptable as commercial sets), and these were not screened out before the weighings for yield records were made.

Sweet corn. In the sweet corn tests, the Golden Bantam variety was used from 1925 to 1934 inclusive, but because of damage to this variety by Stewart's disease, the Golden Cross Bantam was substituted in 1935 and 1936. The planting date was usually about May 10. The hills were placed 36 inches apart each way, and the plants were thinned to three in a hill. In harvesting the corn usually only two pickings were made, tho two of the years three pickings were employed. Records were made on the basis of both count and weight.

Cabbage. Several different varieties of cabbage were used during the experiment. Starting in 1925, Copenhagen Market was used until 1928, but was so severely attacked by yellows that year, that the following year (1929) Bugner was substituted. The Bugner did not prove as resistant to yellows as expected. A crop failure in 1931 and low yields in 1932 resulted in a change to Wisconsin All Seasons in 1933. Crop failure in 1934, led to the planting of Wisconsin Ball Head in 1935 and 1936.

The cabbage seed was sown in outdoor seedbeds about May 1, and the plants were transplanted to the field when about six weeks old.

The rows of cabbage were 3 feet apart, and the plants were set approximately 2 feet apart in the row.

In harvesting the cabbage usually two cuttings were made. Records were kept regarding both the number of heads and the total weight of cabbage trimmed ready for market.

Cucumbers. The variety of cucumber employed thruout the experiment was Snow's Fancy Pickling. The seed was sown about June 1 in rows 40 inches apart with a garden seed drill. The plants were thinned to 8 to 10 inches apart in the row. Treatment for control of foliage diseases, plant lice, and striped beetles was employed whenever necessary.

In harvesting the cucumbers, the field was usually gone over at least twice a week. The aim was to gather at each picking all fruits that were large enough for inclusion in the grade known as "salts." This grade consisted of well-shaped fruits 2½ to 3 inches long and less than 1¼ inches in diameter. There were usually some fruits past this size; these, if well formed, were classified as "cukes" according to the gardeners' practice. Misshapen cucumbers of all sizes were classified as "nubs" (Fig. 1). Records were made of the number and weight of each of these three classes of cucumbers harvested at each picking. The number of pickings per season varied from 8 to 18, the harvest period being from 27 to 54 days in length.

To determine the influence of the different fertilizer treatments on earliness of the cucumber crop, the harvest season was divided into two periods, each representing half the total number of pickings.

EFFECTS OF FERTILIZER ON CUCUMBERS

Very pronounced effects of fertilizer on yields and earliness of pickle cucumbers were apparent. All treatments except one (4-0-4) resulted in significant increases in yield over the adjacent untreated check plots, and also much greater yields during the first half of the harvest season.

Effect on Yields

Series I. In this series, where all plots were given the same cover-crop treatment and comparisons were made between different fertilizers, phosphorus seemed the most important element for cucumbers. Not so much response to nitrogen or potash was evident.

Even a small amount of phosphorus (4 percent) in the fertilizer caused distinct gains both in number and weight of cucumbers. An increase to 8 percent of phosphorus caused much further increases in

FIG. 1.—THREE GRADES OF PICKLE CUCUMBERS

Pickle cucumbers are graded as "nubs" (*top*), "salts" (*center*), and "cukes" (*bottom*). In these tests no consistent differences in percentage of nubs were found that could be attributed to differences in the fertilizer used.

yield. The 4-8-4 fertilizer gave an increase of 46.8 percent by number and 50.3 percent by weight over the adjacent check. When phosphorus was omitted entirely from the fertilizer treatment, yields of cucumbers were not significantly different from those of the adjacent checks.

An increase in the percentage of nitrogen from 0 to 6 resulted in an increase in both number and weight of cucumbers, but the differences in weight were not very marked. This small response to nitrogen could be expected in view of the previous treatment of the plots, for about June 1 of the year before the cucumbers were planted in the rotation, a large crop of sweet clover was plowed under. After producing a crop of cabbage, the land was plowed in the fall and remained fallow until the latter part of May, when the cucumbers were planted. Sufficient nitrogen was probably made available to the plants, especially for the early part of the growing season. The fact that early yields of cucumbers were not increased by application of commercial nitrogen supports this supposition.

Increasing the amount of potassium in the fertilizer made relatively slight differences in the yields. In fact, on the basis of number of cucumbers, the formula containing no potash resulted in as great an increase in yield over the adjacent check plot as the 4-8-4 fertilizer.

TABLE 2.—YIELDS OF CUCUMBERS UNDER DIFFERENT FERTILIZER TREATMENTS
(Average annual yields from 1/40-acre plots)

Treatment	Number of cucumbers				Weight of cucumbers			
	Treated	Check	Increase over check	Odds[1]	Treated	Check	Increase over check	Odds[1]
Series I[2]								
					lb.	*lb.*	*lb.*	
(1) 0-8-4.....	2 207.9	1 516.7	691.2	1666:1	347.0	228.5	118.5	3332:1
(2) 4-8-4.....	2 228.0	1 516.7	711.3	9999:1	350.2	228.5	121.7	9999:1
(3) 6-8-4.....	2 329.9	1 490.4	839.5	9999:1	363.8	225.6	138.2	9999:1
(4) 4-0-4.....	1 432.3	1 490.4	−58.1	3:1	214.1	225.6	−11.5	5:1
(5) 4-4-4.....	1 907.4	1 502.3	405.1	2499:1	290.2	224.6	65.6	9999:1
(6) 4-12-4.....	2 235.4	1 502.3	733.1	9999:1	338.4	224.6	113.8	9999:1
(7) 4-8-0.....	2 084.2	1 372.8	711.4	2499:1	308.3	201.0	107.3	9999:1
(8) 4-8-6.....	2 173.7	1 372.8	800.9	3332:1	324.7	201.0	123.7	9999:1
Series II[3]								
(1) 4-8-4.....	1 979.9	1 320.1	659.8	9999:1	311.4	191.7	119.7	9999:1
(2) Manure....	2 225.0	1 320.1	904.9	9999:1	348.6	191.7	156.9	9999:1

[1]Odds of less than 30 to 1 indicate that there was no significant difference in the yields of the two plots under consideration, while odds greater than 30 to 1 indicate that the difference was significant. [2]Data based on 10 years' records. [3]Data based on 12 years' records.

Series II. In this series, where a comparison was made between 1,000 pounds of complete commercial fertilizer (4-8-4) per acre and 20 tons of manure, without the use of cover crops, both treatments resulted in very marked increases in yield over the adjacent check plots, but the manure treatment showed distinctly larger increases than the fertilizer treatment, both as to total number and total weight of cucumbers harvested (Table 2). The annual increase per acre attributable to the manure treatment amounted to 36,196 cucumbers, or 6,276 pounds of cucumbers. This was an increase of 68.55 percent by number and 81.8 percent by weight.

Such results were to be expected where no cover crop was grown and sufficient time was allowed for the manure to decompose before the cucumbers were planted. The response to manure may indicate that the rotation should have been altered so that cucumbers would have been preceded by a cover crop in Series I.

Effect on Earliness

Since the price of pickle cucumbers on the open market is normally much higher early in the season than late, the quantity harvested dur-

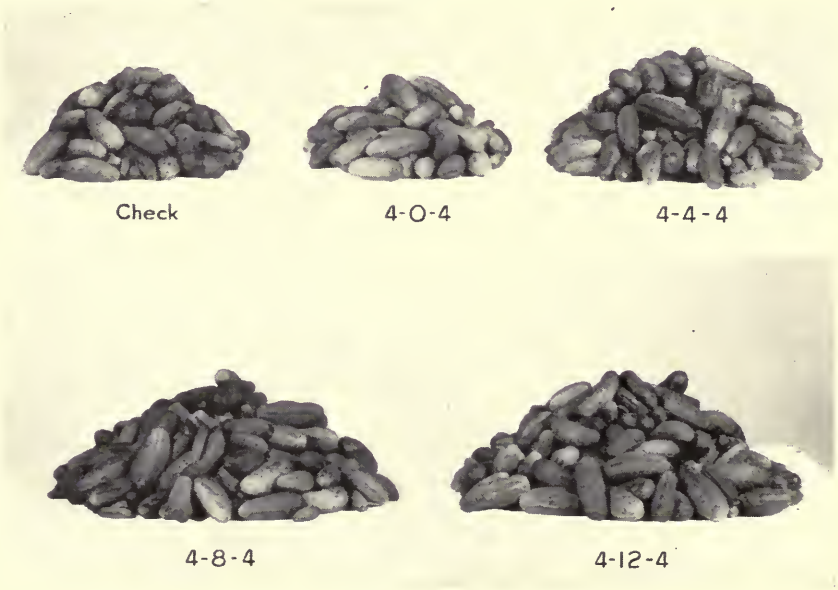

FIG. 2.—RELATIVE EARLY YIELDS OF CUCUMBERS IN PHOSPHORUS SERIES

Average yields during the first half of the harvest season, from 1/40-acre plots receiving a mixed fertilizer carrying different amounts of phosphorus, were as follows: check (no fertilizer), 35.8 pounds; 4-0-4, 29.1 pounds; 4-4-4, 58 pounds; 4-8-4, 84 pounds; 4-12-4, 91.1 pounds.

ing the first half of the harvest period may be a more important factor than total yield in determining the profitableness of the crop.

Series I. In Series I of these experiments no definite relation was shown between volume of early yields and amount of nitrogen in the fertilizer, the yields from the plots receiving no nitrogen whatever being immaterially different from those from the plots receiving the largest amount of nitrogen. Phosphorus, however, produced a very striking difference. The treatment containing no phosphorus resulted in early yields not significantly different from those obtained from the adjacent untreated check; but with each increase in the amount of phosphorus in the fertilizer there was a corresponding increase in the early yield and greater differences between the yield of the treated plot and the adjacent check. The early yield from the plots receiving the 4-12-4 treatment amounted to 3,648 pounds an acre, which was 2,152 pounds more than the early yield of the adjacent untreated check. Fig. 2 shows these differences on a smaller scale.

Series II. The manure treatment resulted in a greater increase in yield of early fruit over the adjacent check than did the complete-commercial-fertilizer treatment, but both treatments gave more than double the yield of the check (Table 3).

TABLE 3.—YIELDS OF CUCUMBERS DURING FIRST HALF OF HARVEST SEASON
(Average annual yields from 1/40-acre plots)

Treatment	Number of cucumbers				Weight of cucumbers		
	Treated	Check	Increase over check	Percentage early	Treated	Check	Increase over check
Series I[1]							
				percent	*lb.*	*lb.*	*lb.*
(1) 0-8-4	564.9	242.5	322.4	25.58	89.2	36.5	52.7
(2) 4-8-4	506.1	242.5	263.6	22.71	84.0	36.5	47.5
(3) 6-8-4	558.4	215.4	343.0	23.96	91.1	35.0	56.1
(4) 4-0-4	188.4	215.4	−27.0	13.15	29.1	35.0	−5.9
(5) 4-4-4	373.5	241.8	131.7	19.58	58.0	37.4	20.6
(6) 4-12-4	577.7	241.8	335.9	25.84	91.2	37.4	53.8
(7) 4-8-0	488.9	207.0	281.9	23.45	76.2	34.5	41.7
(8) 4-8-6	529.6	207.0	322.6	24.36	85.4	34.5	50.9
Average of checks...	.....	226.6	.....	15.41	....	35.8	....
Series II[2]							
(1) 4-8-4	559.9	260.5	299.4	28.27	88.5	36.7	51.8
(2) Manure	658.4	260.5	397.9	29.59	99.3	36.7	62.6

[1]Data based on 10 years' yield records. [2]Data based on 12 years' yield records.

TABLE 4.—CLASSIFICATION OF CUCUMBERS PRODUCED UNDER DIFFERENT FERTILIZER TREATMENTS

(Average annual yields from 1/40-acre plots)

Treatment	Salts		Cukes		Nubs		Total		Percent nubs[3]
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	
Series I[1]									
(1) 0-8-4....	1 380.7	206.9	63.7	32.3	763.3	107.8	2 207.7	347.0	34.57
Check...	898.8	129.8	37.6	19.2	580.2	79.5	1 516.2	228.5	38.26
(2) 4-8-4....	1 406.0	209.8	62.9	32.3	759.1	107.0	2 228.0	349.1	34.07
(3) 6-8-4....	1 481.8	221.3	64.7	32.7	783.6	109.8	2 330.1	363.8	33.63
Check...	875.7	125.5	40.7	19.1	573.8	81.0	1 490.2	225.6	38.50
(4) 4-0-4....	876.4	123.7	35.5	17.9	520.4	72.5	1 432.3	214.1	36.33
(5) 4-4-4....	1 195.5	173.3	50.6	25.9	660.8	91.0	1 906.9	290.2	34.65
Check...	964.2	131.1	34.4	17.4	553.6	75.9	1 552.2	224.4	35.66
(6) 4-12-4...	1 395.0	204.0	57.7	29.6	782.7	104.7	2 235.4	338.3	35.02
(7) 0-8-4....	1 294.8	183.6	52.0	25.8	737.3	98.8	2 084.1	308.2	35.37
Check...	807.4	115.2	29.3	14.3	536.0	71.4	1 372.7	200.9	39.04
(8) 4-8-6....	1 373.1	197.2	55.6	28.1	745.0	99.3	2 173.7	324.6	34.27
Series II[2]									
(1) 4-8-4....	1 223.9	182.9	47.5	24.9	736.1	97.5	2 007.5	305.3	36.66
Check...	793.2	112.1	25.1	12.9	584.0	76.8	1 402.3	201.8	41.71
(2) Manure..	1 412.2	207.6	55.5	28.0	822.3	109.4	2 290.0	345.0	35.90

[1]Data based on 10 years' yield records. [2]Data based on 12 years' yield records. [3]Based on number.

Effect on Grade

In addition to the effects of fertilizer upon yields of cucumbers by count and weight, it is of interest to determine whether there may be any effect of different fertilizers upon the percentage of cucumbers classified as "nubs." All the cucumbers harvested during the progress of this experiment were therefore classified into "salts," "cukes," and "nubs."

No consistent differences were found in percentage of "nubs," that could be attributed to differences in composition of the fertilizers used, tho the percentage was slightly higher on most of the check plots than on the fertilized plots (Table 4).

EFFECT OF FERTILIZER ON ONION SETS

Onion sets responded to fertilizer treatment much less markedly than did pickle cucumbers, but still they were benefited by certain treatments.

Series I. In this series the response of onion sets to nitrogen was quite evident, increasing with increasing amounts of nitrogen up

to 6 percent. The fertilizer containing the most nitrogen (6-8-4) showed the highest yield (396.7 bushels an acre) and the greatest increase (73.5 bushels, or 22.7 percent) over the adjacent check (Table 5).

The consistent response of onion sets to nitrogen in this series could be expected. A cover crop of oats was grown in the fall and plowed down. Fertilizing elements, especially nitrogen, were perhaps not available for the growth of crops planted early the following spring, and any delay or check in the growth of an early, cool-season crop such as onion sets, may reduce its yield.

As the amount of phosphorus in the fertilizer was increased, the difference in yield between the treated plots and the adjacent checks increased until the 4-8-4 formula was reached, but the differences were small and probably not significant. Increasing the phosphorus content of the fertilizer to 12 percent did not further increase the relative yield.

Where there was no potassium in the fertilizer, the increase in yield of onion sets over the adjacent check was not significant; but where 4 percent of potassium was added to the 4-8-0 fertilizer, there was a greater increase in yield over the check than from any other treatment in the series except the 6-8-4 formula. A further increase in the potassium to 6 percent did not cause as great an increase in yield over the check as did the use of the 4-8-4 mixture. Altho the highest yields of onion sets came from the plots receiving the fertilizer contain-

TABLE 5.—YIELDS OF ONION SETS UNDER DIFFERENT FERTILIZER TREATMENTS
(Average annual yields from 1/40-acre plots)

Treatment	Treated	Check	Increase over check	Odds
		Series I[1]		
	lb.	*lb.*	*lb.*	
(1) 0-8-4	379.1	318.5	60.6	132:1
(2) 4-8-4	386.0	318.5	67.5	1428:1
(3) 6-8-4	396.7	323.2	73.5	1600:1
(4) 4-0-4	365.7	323.2	42.5	81:1
(5) 4-4-4	364.0	301.1	62.9	1110:1
(6) 4-12-4	360.7	301.1	59.6	400:1
(7) 4-8-0	331.9	304.4	27.5	22:1
(8) 4-8-6	359.3	304.4	54.9	163:1
		Series II[2]		
(1) 4-8-4	342.9	277.7	65.2	325:1
(2) Manure	324.0	277.7	46.3	62:1

[1]Data based on 10 years' yield records. [2]Data based on 12 years' yield records.

ing the highest percentage of nitrogen, this crop seemed to get along better without any nitrogen in the fertilizer than without any potassium.

Series II. In this series, where no cover crops were used and where a comparison was made between yields produced by 1,000 pounds of a complete commercial fertilizer and by 20 tons of manure, both treatments gave significant increases in yield of onion sets over the adjacent check plots. In a twelve-year average the increases were somewhat greater from the commercial fertilizer than from the manure.

It was to be expected that this crop in the Series II tests would be benefited less than the cucumbers by manure.

Soil tests made early in the spring showed that the manure plots were low in available nitrogen. The appearance of the plants at the time of the tests indicated nitrogen deficiency. It is possible, therefore, that a small early application of nitrogen on the manure plot would have given a substantial increase in yield.

RESULTS WITH SWEET CORN

Of the four crops in the experiment, sweet corn was least responsive to the fertilizer treatments used in these tests. While the increases in yields resulting from moderate amounts of nitrogen, phosphorus, and potassium were large enough to be significant, it was obvious that either the rates of application were too high or the method of application was ineffective for profitable increases in yield.[1] When properly fertilized, corn following a cover crop of rye and vetch would be expected to show a marked response to nitrogen. That this was not the case is further evidence that the best fertilizer or method of application for corn was not included in this experiment.

Series I. There was no significant increase in yield, either in number or weight of ears, as a result of using nitrogen in the fertilizer formula (Table 6). In the phosphorus series of plots the highest number of ears and greatest increase over the adjacent check was on the plots treated with the 4-4-4 fertilizer, not with the 4-8-4 or the 4-12-4 combination.

Fertilizer containing 4 percent of potassium produced somewhat larger increases over the adjacent check than a fertilizer containing no potash, but increasing the potash content to 6 percent caused no corresponding increase in yield.

[1]Lack of profitable response of sweet corn to large applications of fertilizer has previously been reported as the result of tests at Urbana and experience of commercial growers. See Bulletin 364 of this Station and Circular 439.

TABLE 6.—YIELDS OF SWEET CORN UNDER DIFFERENT FERTILIZER TREATMENTS
(Average annual yields from 1/40-acre plots)

Treatment	Number of ears				Weight of corn (unhusked ears)			
	Treated	Check	Increase over check	Odds	Treated	Check	Increase over check	Odds
Series I[1]								
					lb.	*lb.*	*lb.*	
(1) 0-8-4.....	349.5	322.6	26.9	38:1	147.0	129.3	17.7	28:1
(2) 4-8-4.....	352.8	322.6	30.2	38:1	148.0	129.3	18.7	144:1
(3) 6-8-4.....	361.6	329.6	32.0	66:1	149.7	134.9	14.8	31:1
(4) 4-0-4.....	349.5	329.6	19.9	22:1	143.2	134.9	8.3	25:1
(5) 4-4-4.....	356.6	317.3	39.3	9999:1	147.3	127.5	19.8	1999:1
(6) 4-12-4.....	351.9	317.3	34.6	144:1	146.1	127.5	18.6	83:1
(7) 4-8-0.....	347.5	324.0	23.5	38:1	140.9	132.0	8.9	9:1
(8) 4-8-6.....	350.2	324.0	26.2	75:1	148.6	132.0	16.6	83:1
Series II[2]								
(1) 4-8-4.....	342.3	299.4	43.9	3332:1	138.8	116.2	22.6	1666:1
(2) Manure....	328.0	299.4	28.6	330:1	137.5	116.2	21.3	1110:1

[1]Data based on 11 years' yield records. [2]Data based on 12 years' yield records.

Series II. In this series, where no cover crop was used, the plots treated with 1,000 pounds of a complete commercial fertilizer (4-8-4) per acre and those treated with manure at the rate of 20 tons per acre gave significant increases in yield over the untreated checks. The differences between the two treatments, however, were too slight to be significant.

RESULTS WITH CABBAGE

Cabbage showed very definite response to nitrogen and phosphorus but not to potassium where sweet clover was plowed down before planting. These responses are particularly striking since the sweet clover would be expected to furnish available nitrogen and phosphorus. The fact that maximum yields were not obtained with large applications of manure indicates that the manure perhaps should have been supplemented with superphosphate.

Series I. In this series all but three treatments produced significant increases in yield over the adjacent checks in number of heads, and all except one treatment produced significant increases in total weight of crop (Table 7).

When the amount of nitrogen in the formula was increased, there

TABLE 7.—YIELDS OF CABBAGE UNDER DIFFERENT FERTILIZER TREATMENTS
(Average annual yields from 1/40-acre plots)

Treatment	Number of heads				Weight of crop (trimmed for market)			
	Treated	Check	Increase over check	Odds	Treated	Check	Increase over check	Odds
Series I[1]								
					lb.	*lb.*	*lb.*	
(1) 0-8-4.....	113.9	108.5	5.3	8:1	300.0	216.3	83.7	1428:1
(2) 4-8-4.....	128.9	108.5	20.4	9999:1	338.3	216.3	122.0	2499:1
(3) 6-8-4.....	128.7	112.4	16.3	3332:1	375.7	223.5	152.2	832:1
(4) 4-0-4.....	109.8	112.4	−2.5	1:1	251.8	223.5	28.3	4:1
(5) 4-4-4.....	120.2	106.4	13.8	28:1	316.0	216.7	99.3	600:1
(6) 4-12-4.....	131.9	106.4	25.5	832:1	386.1	216.7	169.4	9999:1
(7) 4-8-0.....	134.9	120.0	14.8	9999:1	378.6	261.9	116.7	555:1
(8) 4-8-6.....	136.5	120.0	16.5	40:1	395.7	261.9	133.9	555:1
Series II[2]								
(1) 4-8-4.....	125.4	90.9	34.5	1666:1	388.0	232.9	155.1	3332:1
(2) Manure...	120.4	90.9	29.5	713:1	374.1	232.9	141.2	1666:1

[1]Data based on 9 years' yield records. [2]Data based on 8 years' yield records.

was a definite increase in the weight of the crop, each increment in nitrogen resulting in a greater yield. The highest concentration of nitrogen (6 percent) resulted in no more heads than the 4-percent formula, but the heads were larger. Use of the fertilizer containing 6 percent of nitrogen increased the yield 68.1 percent over the adjacent checks, an increase equivalent to 6,088 pounds an acre.

The need of liberal amounts of phosphorus for the production of cabbage is clearly shown by the response of this crop to increasing amounts of this element. The greatest increase in yield over the adjacent check was from the treatment containing the most phosphorus, each increase in the amount of phosphorus being associated with a definite increase in the weight of the crop. In number of heads, also, there was a progressive increase as the amount of phosphorus was increased.

The treatment containing the most phosphorus resulted in an increase over the adjacent check of 6,776 pounds (more than 3 tons) an acre, or 78.17 percent.

Varying the amounts of potassium in the fertilizer caused much less variation in yield than when the quantity of nitrogen or phosphorus was varied, nearly as good yields being obtained when there was no potassium in the fertilizer as when there was the largest amount.

Series II. Both treatments in Series II—20 tons of manure and 1,000 pounds of a complete commercial fertilizer (4-8-4)—produced significant increases in yield over the adjacent untreated checks. This was true whether yields were measured in number of heads or in weight of trimmed cabbage. Owing to crop failures some years, data on this series are available for only eight years. As an average for the eight years, the yields were somewhat higher from the commercial-fertilizer treatment than from the manure treatment.

YIELDS AND FERTILIZER COST

From the market gardener's standpoint, the increases in yield obtained by using a given fertilizer must of course be considered in relation to the cost of the fertilizer. Tables 8 and 9 throw light on this aspect of the experiments. The yields are given in terms of market units per acre.

TABLE 8.—COST OF FERTILIZER MATERIALS PER ACRE AND INCREASE IN YIELD OVER ADJACENT CHECK

Treatment		Increase in yield			
Material	Cost per acre[a]	Cucumbers	Onion sets	Sweet corn	Cabbage
		Series I			
		60-lb. bags	*40-lb. bu.*	*doz. ears*	*cwt.*
(1) 0-8-4	$ 7.37	79.0	60.6	89.2	33.4
(2) 4-8-4	12.59	81.1	67.5	100.6	48.8
(3) 6-8-4	15.21	92.1	73.5	106.2	60.9
(4) 4-0-4	7.27	−7.7	42.5	66.3	11.9
(5) 4-4-4	9.93	43.7	62.9	130.9	39.9
(6) 4-12-4	15.25	75.9	59.6	114.2	67.8
(7) 4-8-0	10.54	71.5	27.5	78.2	46.7
(8) 4-8-6	13.61	82.4	54.9	88.6	53.1
		Series II			
(1) 4-8-4	12.59	71.5	65.2	147.2	62.0
(2) Manure	30.00	82.5	46.3	106.9	56.5

[a]Based upon prices of the materials entering into these fertilizers, delivered at Des Plaines, Illinois, in the spring of 1939: nitrate of soda, $41 per ton; ammonium sulfate, $34.93; superphosphate (20-percent) $21.40; muriate of potash, $41.32.

High Cost of Nitrogen

It is true that as the amount of nitrogen in the fertilizer applied to the plots in Series I was increased from 0 to 4 to 6 percent, the

yields of all four crops increased in relation to the check plot. But, with one exception, the cost of the fertilizer per unit of crop increase also advanced. The exception was in the cabbage crop, the cost of the 6-8-4 treatment per unit of crop increase being slightly lower than that of the 4-8-4 treatment.

Under the conditions of this experiment and at the prices for fertilizer indicated, it would probably not pay to use nitrogen in the fertilizer formula for cucumbers or sweet corn.

TABLE 9.—COST OF FERTILIZER PER UNIT OF INCREASE IN YIELD

Treatment	Cucumbers	Onion sets	Sweet corn	Cabbage
		Series I		
	60-lb. bags	*40-lb. bu.*	*doz. ears*	*cwt.*
(1) 0-8-4	$.093	$.122	$.083	$.221
(2) 4-8-4	.155	.186	.125	.258
(3) 6-8-4	.165	.207	.143	.250
(4) 4-0-4	(1)	.171	.110	.611
(5) 4-4-4	.227	.158	.076	.249
(6) 4-12-4	.201	.256	.134	.225
(7) 4-8-0	.147	.383	.135	.226
(8) 4-8-6	.165	.248	.154	.256
		Series II		
(1) 4-8-4	.176	.193	.086	.203
(2) Manure	.364	.648	.281	.531

[1]The cucumber yield from the 4-0-4 treatment was less than the yield from the check plot.

Phosphorus an Important Element

Phosphorus proved an important constituent of the fertilizer mixtures used in these tests. In fact, when it was omitted from the mixture, the cucumber yield was lower than it was from the adjacent check plot and the increase in cabbage yield was so small that the unit cost of the fertilizer was excessive. In the phosphorus series it was the treatment that contained the most phosphorus (4-12-4) and was the most expensive that produced increases in cabbage yields at the lowest cost per unit of crop.

With onion sets and sweet corn the unit cost of the increases produced on the plots where phosphorus was omitted was greater than it was from the plots where the 4-4-4 mixture was applied. The most favorable treatment for these crops in the phosphorus series, judged by the cost per unit of crop increase, was the 4-4-4 mixture.

Moderate Applications of Potash Sufficient

For cucumbers each additional amount of potash in the fertilizer increased slightly the cost per unit of increased yield. For onion sets, however, the greatest cost per unit of increase was with a mixture containing no potash; consistently good results were obtained with a treatment containing 4 percent of potash.

Varying the amount of potash in the fertilizer for sweet corn seemed to have no marked effect on the difference in unit cost of increases. Increased cabbage yields cost slightly more when potash was used in the fertilizer than when no potash was used.

High Cost of Manure Treatment

In Series II, where a comparison was made between the use of a 4-8-4 fertilizer and 20 tons of manure an acre, three of the crops—onion sets, sweet corn, and cabbage—gave larger increases in yield over the checks when the commercial fertilizer was applied (Table 8). Because of the high cost of the manure, the unit cost of the increases which the manure produced in the yields of each of these four crops was from two to three times as great as the cost of the increases from the commercial fertilizers (Table 9).

SUMMARY

The scarcity of animal manure, formerly used extensively as a fertilizer for market gardens, and recognition that it does not contain in the correct proportions the fertilizing elements needed for garden crops, have led to many studies of substitute materials. Illinois has a special interest in this problem because the production of vegetables for local markets is an important industry in the state.

Since onion sets, sweet corn for market, cabbage, and pickle cucumbers are four vegetable crops of major importance in the market gardens of northeastern Illinois, a plan was devised for growing them in a four-year rotation. Three cover crops for green manuring were included in each four-year period, and these were supplemented by various combinations of fertilizing materials containing nitrogen, phosphorus, and potassium.

The results of these tests carried on from 1925 thru 1936 at the Cook County Branch Experiment Station, were as follows:

1. *Cucumbers* gave a very marked response to phosphorus treatment, the yields advancing progressively when phosphorus in the fertilizer was increased from 0 to 4 to 8 percent. Phosphorus also promoted the early development of the crop.

2. *Onion sets* responded definitely to nitrogen in commercial form, the highest yield and greatest increase over the adjacent check being obtained from the treatment containing the most nitrogen (6-8-4). Omitting potash from the fertilizer markedly reduced the yield of onion sets.

3. Of the four crops in this experiment, *sweet corn* was least responsive to the fertilizer treatments used.

4. *Cabbage* showed very definite response to nitrogen and phosphorus but not to potash.

5. In the series of plots where cover crops were not grown and where the object was to compare the effectiveness of manure with that of commercial fertilizer, cucumbers produced higher yields from manure than from commercial fertilizer, while onion sets, sweet corn and cabbage gave the best results with commercial fertilizer.

6. Costs of increased yields were so high under some treatments as to render the treatments impractical.

7. Economical increases in the yields of cucumbers, onion sets, and cabbage were obtained under certain treatments; but not one of the treatments here reported caused sufficient increase in the yield of corn to justify its use under the conditions of this experiment.

8. Unit costs of increased yields were much lower when a complete commercial fertilizer (4-8-4) was used than when manure was applied.

SUGGESTED TREATMENTS

Considering both the increases in yield and the costs of those increases, the following fertilizer treatments are suggested for the respective crops in this four-year rotation when grown under conditions similar to those in this experiment:

1. For cucumbers an 0-8-4 fertilizer.[1]

2. For onion sets a 4-8-4 fertilizer following a cover crop plowed under in the fall.

3. For sweet corn no fertilizer following a cover crop of rye and vetch plowed under in early spring.

4. For late cabbage following a cover crop of sweet clover, a 4-12-4 fertilizer.

[1]An 0-10-5 fertilizer, adjusted as to quantity, would doubtless have given similar results.

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